

1 **SOUND ACTIVATED SAFETY SYSTEM FOR A REDUCTION MILL**

2 **FIELD OF THE INVENTION**

3 The present invention relates generally to the art of
4 reduction mills and more particularly to reduction mills of the
5 type which may be used for such operations as the comminuting
6 of yard and garden waste or refuse into small pieces which are
7 more biodegradable or recyclable. More specifically, the
8 present invention, provides a method and device for preventing
9 and/or minimizing damage to such shredding equipment at the
10 hammer roll area. Still more specifically, to a sound
11 activated system for reversing the direction of movement of the
12 conveyors or pinch rolls feeding debris into the shredding area
13 of the reduction mill to prevent introduction of non-grindable
14 materials into the hammer roll area.

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16 **BACKGROUND OF THE INVENTION**

17 Reduction equipment has been known for a number of years
18 and the sizes and applications of such devices vary widely. In
19 the yard and garden equipment industry, reduction mills are
20 becoming more commonplace as states and municipalities mandate
21 the composting of yard and garden waste, or as operators of
22 composting sites find that their operations can be run more
23 efficiently if waste such as branches, fallen trees, and the
24 like are comminuted before the material is put into windrows or

1 piles. In the refuse industry reduction mills are also
2 becoming commonplace as the Federal and State governments
3 mandate strict requirements for landfills. The smaller pieces
4 resulting from such operations biodegrade more quickly under
5 suitable moisture and oxygen conditions and the volume required
6 for the ultimate disposal of the material is also reduced.

7 Such machines have included a generally rectangular
8 collection hopper which can be loaded by front end loaders and
9 the like with debris to be comminuted. The floor of the bin is
10 a first endless conveyor adapted to move the debris from a rear
11 portion to the opposite end of the machine. Prior machines
12 have also included an upper conveyor, inclined at an acute
13 angle with respect to the floor conveyor, or an upper feed roll
14 adapted to assist in moving material toward the nip formed
15 between the two conveyors. A rotating hammer mill has been
16 located at the outlet of the nip to receive material being
17 moved by the conveyors. The hammer mill includes a rotating
18 hammer roll having plurality of hammer knife elements which
19 pass in close proximity to a stationary cutting surface, all as
20 is well known in the comminuting art for dividing the material
21 into fine pieces which are discharged at the rear of the
22 machine. Various modifications which are not relevant to the
23 present invention include providing screens on the rear of the
24 hammer mill to cause particles to stay in the shredding section

1 for a longer period of time so that the average particle size
2 can be reduced, and various devices for directing the discharge
3 to a desired outlet location, which could be a windrow, a pile
4 or the like.

5 In such prior equipment, one frequently encountered
6 problem has been the introduction of unshredable material into
7 the machines when large bunches of the debris are being forced
8 by the two conveyors toward the hammer roll. Unshredable
9 material may include stones, concrete or metal hidden in the
10 debris. Due to a lack of suitable equipment to detect such
11 unshredable material in the prior art machines, unshredable
12 material has resulted in serious and costly damage to the
13 equipment. Removal of the unshredable material from the hammer
14 mill area necessarily requires the equipment to be completely
15 shut down so that the conveyor and hammer may be cleaned out
16 manually. Only after the debris has been cleaned from the
17 machine can the damage be assessed and repaired. Such
18 operations result in reduced efficiency and substantially
19 increased operating costs for the equipment, and a system which
20 would overcome this problem would represent a substantial
21 advance in this technology.

22 Attempts at designing the equipment to withstand
23 introduction of the unshredable material have met with minimal
24 success. These devices generally center around screens or

1 spring loaded by-pass gates.

2 For example, U.S. Patent No. 3,082,963, teaches a hammer
3 grinder. The device includes a vertical supply passage above
4 the hammer roll and a semi-cylindrical grid below the hammer
5 roll. A casing is located adjacent to the supply passage for
6 collecting unshredable material. The unshredable material is
7 removed from the hammer grinder through an opening in the lower
8 part of the casing.

9 U.S. Patent No. 3,540,665, teaches a scrap breaking
10 device. The device includes a supply passage for the scrap
11 positioned above the hammer roll and a semi-cylindrical grid
12 below the hammer roll which forms a partition between the
13 hammer roll and the a discharge passage. The scrap first
14 enters the supply passage via a conveyor and falls down into
15 the hammer roll area. The objects which are not broken are
16 thrown upward to a grid positioned above the conveyor. Objects
17 remaining on the grid can be removed manually after the hammer
18 roll is shut down.

19 U.S. Patent No. 4,378,094, teaches a material reducing
20 mill. Material is delivered to the mill via a conveyor which
21 allows the material to fall onto the rotating hammer roll. The
22 device is also provided with a by-pass gate positioned adjacent
23 to the fall of material. The by-pass gate is manually operable
24 to direct unshredable material away from the hammer roll. When

1 an operator hears a unshredable object strike the hammer roll
2 a lever is actuated to move a gate into an open position,
3 thereby allowing the material in the area to be by-passed
4 around the hammer roll assembly. The result is that the chute
5 formed thereby will direct a quantity of material, including
6 the unshredable material, into the by-pass passage.
7 Concurrently with the operation of the by-pass gate, the drive
8 for the conveyor is reversed so that the by-passed material can
9 be directed into a container.

10 U.S. Patent No. 4,449,673, teaches a reduction mill having
11 a rotating hammer roll and a hydraulically displacable grate
12 and by-pass door assembly. The grate assembly being pivotally
13 displacable by power means, as a single unit, from the hammer
14 roll portion to achieve ready access to the grate assembly for
15 reversal or replacement of worn sections. The by-pass door is
16 pivotally displacable to a first position which permits quick,
17 safe and efficient removal of unshredable materials from the
18 product stream of the reduction mill without stopping hammer
19 roll rotation. The pivotal displacement of the by-pass door is
20 selectively powered by the same power means or unit which
21 pivotally displaces the grate system for access to the hammer
22 roll and grate assembly.

23 Other devices are aimed at allowing easy access to replace
24 broken or worn components instead of preventing unshredable

1 material from entering the hammer mill the device. For
2 example, U.S. Patent No. 4,202,503, teaches a hammer mill
3 comprising a housing and mounted within the housing a rotor and
4 a breaker and screening assembly which cooperates with the
5 rotor is constructed so that the breaker and screening assembly
6 may be angularly displaced between an operative position
7 adjacent the rotor and a servicing position at which access may
8 be had to the breaker and screening assembly from outside the
9 casing.

10 Accordingly, what is lacking in the prior art is a cost
11 effective safety system for a reduction mill that is capable of
12 effectively preventing or minimizing damage caused to the mill
13 components by the introduction of unshredable material. The
14 safety system should achieve objectives such as quick response
15 and reliable performance. The safety system should include
16 packaging flexibility for installation on various new and pre-
17 existing hammer mill configurations including retrofitting onto
18 pre-existing hammer mills with minimal modification.

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1 **SUMMARY OF THE INVENTION**

2 The present invention provides a sound activated detection
3 system disposed within the conveyor and/or hammer roll area of
4 a reduction mill for detecting unshredable materials fed into
5 the machine. More specifically, an embodiment of this
6 invention comprises a unshredable debris detector disposed in
7 operative relationship in the material input path and includes
8 a transducer, preferably a piezoelectric crystal, acoustically
9 coupled to a sensing surface disposed transversely across a
10 portion of the input path. Alternative embodiments may include
11 one or more accelerometers, microphones, or other vibration or
12 acoustic sensors either alone or in conjunction with the
13 transducer for detecting the unshredable material. The present
14 invention further features a conveyor system wherein the
15 conveyor(s) are automatically reversed for a predetermined
16 amount of time when a unshredable object is detected. The
17 reversal of the direction of movement of the endless
18 conveyor(s) allows the unshredable object, which could damage
19 the equipment, to be removed from the waste material.

20 The unshredable detector incorporates means for selecting
21 the detected "unshredable" signal from spurious signals or
22 extraneous false vibrations in order to actuate a threshold
23 means. More specifically, an embodiment of the invention
24 incorporates acoustic isolation means coupled to the sensing

1 surface to suppress or isolate extraneous false acoustic
2 vibrations of the reduction mill of the same character as the
3 "unshredable" detection signal from the sensing device;
4 whereas, a further embodiment of this invention includes a
5 circuit having at least one filtering means for selecting the
6 detected stone signal from the spurious signals of the same
7 character as the detected stone signal. In addition, an
8 embodiment of this invention includes means for controlling the
9 direction of flow of material and unshredable debris gathered
10 therewith such that all of the material and foreign objects,
11 conveyed through the mill are directed towards the sensing
12 device to impact therewith to assure detection of all of the
13 unshredable foreign objects mixed therewith.

14 Accordingly, it is an objective of the present invention
15 to provide an acoustic unshredable material detection system
16 for a reduction mill.

17 Yet an additional objective of the present invention to
18 provide an acoustic array that is capable of detecting
19 unshredable material located within the material flow through
20 a reduction mill.

21 It is a further objective of the present invention to
22 provide a controller capable of receiving an electrical signal
23 from an acoustic sensor and transmitting an electrical signal
24 to a solenoid.

1 A still further objective of the present invention is to
2 provide a first acoustic array positionable within a reduction
3 mill.

4 Another objective of the present invention to provide a
5 sounding plate for the first acoustic array.

6 Yet another objective of the present invention is to
7 provide a kit for a reduction mill capable of detecting
8 unshredable material within the debris flow through the
9 reduction mill to prevent and/or reduce damage to the hammer
10 roll that is simple to install and which is ideally suited for
11 original equipment and aftermarket installations.

12 Yet another objective of the present invention is to
13 provide a kit for a reduction mill capable of detecting
14 unshredable material within the debris flow through the
15 reduction mill that can be inexpensively manufactured and which
16 is simple and reliable in operation.

17 Other objects and advantages of this invention will become
18 apparent from the following description taken in conjunction
19 with the accompanying drawings wherein are set forth, by way of
20 illustration and example, certain embodiments of this
21 invention. The drawings constitute a part of this
22 specification and include exemplary embodiments of the present
23 invention and illustrate various objects and features thereof.

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1 BRIEF DESCRIPTION OF THE FIGURES

2 Figure 1 is a side schematic illustration of a mobile
3 waste shredder according to a preferred form of the present
4 invention showing the overall layout of the equipment.

5 Figure 2 is a schematic illustration of one type of a
6 conveyor system capable of utilizing the present invention,
7 arrows indicating normal direction of travel and illustrating
8 waste material approaching the nip area of the conveyor;

9 Figure 3 is a schematic illustration of a dual conveyor
10 system capable of utilizing the present invention, arrows
11 indicating normal direction of travel and illustrating waste
12 material approaching the nip area of the conveyors;

13 Figure 4 is a partial side view illustrating one
14 embodiment of the present invention;

15 Figure 5 is a partial side view illustrating one
16 embodiment of the present invention;

17 Figure 6 is a schematic in block form illustrating one
18 embodiment of the present invention;

19 Figure 7 is a schematic in block form illustrating an
20 alternative embodiment of the present invention;

21 Figure 8 is a schematic in block form illustrating an
22 alternative embodiment of the present invention;

23 Figure 9 is a graphic illustration of the characteristic
24 amplitude as a function of frequency for shredable material and

1 unshredable debris impacting the acoustic sensing device of the
2 instant invention.

1 DETAILED DESCRIPTION OF THE INVENTION

2 Although the invention is described in terms of a
3 preferred specific embodiment, it will be readily apparent to
4 those skilled in this art that various modifications,
5 rearrangements and substitutions can be made without departing
6 from the spirit of the invention. The scope of the invention
7 is defined by the claims appended hereto.

8 In the following description, a mobile hammer mill is
9 discussed. As illustrated generally in FIGS. 1-3, a mobile
10 hammer mill designated generally as 10 is configured to receive
11 and comminute waste including brush, branches, trees, refuse
12 and the like. The mobile hammer mill 10 includes a frame 12 on
13 which is mounted a hopper 14 for receiving waste material which
14 may be dumped into hopper 14 by a front end loader or other
15 conventional methods. Disposed along the floor of hopper 14 is
16 a lower or floor conveyer 16 which cooperates with an upper
17 feed roll 17 (FIG. 2) or upper conveyor 18 (FIG. 3) to deliver
18 the waste to a hammer section designated generally as 20.

19 Hammer section 20 includes a rotatable hammer roll 22
20 driven by an engine 24. Hammer roll 22 is mounted on a shaft
21 26 and includes a plurality of fixed or pivotable hammer knife
22 elements 28 which pivot outward into proximity with stationary
23 cutting bars 30 when hammer roll 22 rotates. As waste material
24 moves into the hammer section 20, the waste material is sheared

1 into pieces between the moving hammers 28 and the stationary
2 cutting bars 30.

3 Waste material is supplied to hammer section 20 by at
4 least a lower conveyor 16 and may include an upper feed roll 17
5 (FIG. 2) or upper conveyer 18 (FIG. 3). The lower conveyer 16
6 is an elongated endless conveyer having a first end 34 disposed
7 towards the hopper 14 and a second end 32 disposed towards
8 hammer section 20. Lower conveyer 16 rotates around an idler
9 gear shaft assembly 36 located at its second end 32 and is
10 driven by a driving gear shaft assembly 38 located at its first
11 end 34.

12 A feed roll 40 is positioned between lower conveyer first
13 end 32 and hammer mill 22. Feed roll 40 receives waste
14 delivered from lower conveyer 16 and assists in forcing the
15 waste into hammer section 20. Preferably, feed roll 40 is
16 driven by a roller chain 42 connected to a sprocket 44 mounted
17 on driving gear shaft 38.

18 The optional upper feed roll 17 is disposed in proximity
19 to hammer section 20. Upper feed roll 17 driven by a driving
20 gear shaft assembly 51 forms a narrower nip area 54 through
21 which material passes before entering hammer roll 22. As shown
22 in the right side schematic view of FIG. 2, during normal
23 operation upper feed roll 17 rotates in a counterclockwise
24 direction (as viewed from the right) while lower conveyer 16

1 and feed roll 40 both rotate in the clockwise direction to
2 cooperate in forcing the waste material into hammer mill 22.

3 The optional upper conveyer 18 (FIG. 3) includes a first
4 end 46 disposed in proximity to hammer section 20 and a second
5 end 48 disposed generally away from hammer section 20.
6 Conveyer 18 is an elongated endless conveyer driven by a
7 driving gear shaft assembly 50 disposed at second end 48 and
8 further rotating about an idler gear shaft assembly 52 disposed
9 at first end 46. The upper conveyer 18 is preferably oriented
10 so that it forms an acute angle with lower conveyer 16 wherein
11 first end 32 of lower conveyer 16 and first end 46 of upper
12 conveyer 18 form a narrower nip area 54 through which material
13 passes before entering hammer roll 22. As shown in the right
14 side schematic view of FIG. 3, during normal operation upper
15 conveyer 18 rotates in a counterclockwise direction (as viewed
16 from the right) while lower conveyer 16 and feed roll 40 both
17 rotate in the clockwise direction to cooperate in forcing the
18 waste material into hammer mill 22.

19 In the embodiments illustrated in FIGS. 1-3, floor
20 conveyer 16 is driven by a hydraulic motor (not shown) by
21 conventional means well known in the art. Similarly, upper
22 feed roll 17 or conveyer 18 are driven by a hydraulic motor
23 (not shown) connected to driving gear shaft assembly 50 by
24 conventional means well known in the art. In general, engine

1 24 drives a hydraulic pump of conventional configuration to
2 supply pressurized fluid to the hammer mill hydraulic system to
3 control the speed and direction of the conveyors 16, 18, and/or
4 feed rolls 17, 40 as well as the hammer roll 22. The control
5 circuitry used to control the hydraulic system is conventional
6 circuitry as would be used by one of ordinary skill in the art
7 to control solenoid valves. Of course, the conventional
8 circuitry can be modified according to the type of valves,
9 location of valves or type of switches utilized throughout the
10 system. Preferably, a manual override switch is also connected
11 into the control circuitry so that the lower conveyor can be
12 reversed manually as well as automatically. In a most
13 preferred embodiment the control circuitry also includes a
14 self-check circuit (not shown) capable of assuring electrical
15 connection between the present invention safety device and the
16 pre-existing electric controls for the reduction mill.

17 FIG. 4 and 5 depict, in part, the apparatus comprising the
18 present invention. An acoustic sensing device 70 including a
19 sensor bar 72, preferably a steel bar or plate, and an acoustic
20 sensing transducer 74 attached to the bar is disposed generally
21 across the width of the floor of the conveyor 16. The acoustic
22 sensing device 70 may be positioned between the conveyor 16 and
23 the lower feed roll 40, between the lower feed roll 40 and the
24 hammer area 20 or adjacent to any of the stationary plates 30.

1 The transducer 74 typically, a disk shaped piezoelectric
2 crystal is attached to the sensing bar 72 or inserted in a
3 contoured recess located in the backside of the bar, away from
4 the material flow, and is secured therein in any appropriate
5 manner. In response to material including unshredable debris,
6 e.g. stones, metal and the like, striking the upper surface of
7 the sensing bar 72 causing acoustic vibrations therein, the
8 piezoelectric crystal or transducer 74 detects the acoustical
9 vibrations and generates electrical signals, along lines or
10 circuit leads 76. The frequency and amplitude of the
11 electrical signals vary as a function of the characteristic of
12 the acoustic vibrations in the bar as a result of shredable
13 material and/or unshredable debris impact. The electrical
14 signals, moreover, are coupled to appropriate circuit means for
15 detection of the unshredable debris disposed in the shredable
16 material.

17 Referring now to FIG. 6, a processing circuit 78,
18 illustrated in block diagram form, provides a signal 80
19 indicative of the presence of unshredable debris within the
20 shredable material. The circuit 78 includes a buffer circuit
21 82 which receives the electrical signals from the piezoelectric
22 crystal in response to vibrations of the bar 72 and provides a
23 properly matched interface between the remainder of the
24 processing circuitry and the transducer 74. From the buffer

1 circuit 82, the signals are coupled to a bandpass filter
2 circuit 84. The acoustic sensing bar 72 has a spectrum of line
3 frequencies to which it is mechanically resonant, wherein these
4 frequencies are excited by impact of material against the bar.
5 It should be noted, however, that these line frequencies do not
6 stand out, because the bar is well damped, as explained
7 hereinbelow, and because the excitation arises from many
8 incoherent impulses.

9 The frequencies are distinguishable only in a broader
10 sense, which results from the fact that the impact of a hard
11 surface material is able to generate higher frequency sound.
12 This results in the acoustic energy from impact being
13 concentrated into different bands, with the distribution of
14 energy of unshredable debris impacts being at a higher
15 frequency than the energy distribution of softer surface
16 materials such as wood. FIG. 9 is a graphic illustration of
17 the characteristic amplitude as a function of frequency for
18 shredable material and unshredable debris impacting the bar.
19 As shown, the characteristic frequencies 92 excited by
20 unshredable debris, although generally of greater frequency
21 than the frequencies 94 excited by a softer surface such as
22 wood or leaves, are not rigidly fixed within the frequency
23 spectrum. Accordingly, the value of the resonant frequencies
24 for a particular sensing device should be measured so that the

1 center frequency of the bandpass filter 84 may be aligned to
2 envelop the greater or higher in value resonance frequencies
3 induced by the hard object or unshredable debris to be
4 detected. In addition, the bandwidth of the bandpass filter 84
5 is also significant and should be chosen to best match the time
6 characteristics of the impact signal. A wideband allows
7 greater response to initial high amplitude signals induced
8 immediately after impact, whereas a narrow bandwidth has the
9 effect of averaging the response over longer duration.
10 Accordingly, the bandwidth of the bandpass filter circuit 84 is
11 chosen therebetween depending upon the characteristics of the
12 signals 92 transmitted by the sensing bar 72 in cooperation
13 with the piezoelectric crystal transducer 74. The bandpass
14 filter circuit 84 attenuates all signals not falling within the
15 passband, whereas, those signals whose frequencies fall within
16 the passband and thereby initially represent the detection of
17 unshredable debris in the conveyor area or the hammer area are
18 coupled to a threshold comparator circuit 86 (FIG. 6). The
19 threshold comparator circuit 86 compares the amplitude of the
20 signal from the bandpass filter 84 with the amplitude of a
21 preselected or predetermined threshold value deemed to be
22 indicative of unshredable debris and generates the signal 80
23 indicative of the presence of the unshredable debris when the
24 threshold value is exceeded. The actuating signal 80 may be

1 coupled to any suitable actuation device such as warning means,
2 lights or alarms, or conveyor reversing means such as a
3 solenoid activated hydraulic valve well known in the art.

4 As indicated above, spurious or false signals of the same
5 character or characteristics as the unshredable debris signals
6 to be detected may be induced within the hammer mill, and more
7 specifically, within the acoustic sensor 70 due to the
8 interaction of, for example, the moving mechanical parts within
9 the reduction mill or due to noises of similar character as a
10 unshredable debris impact conducted to the sensor bar from
11 outside the flow of material within the hopper and conveyor
12 areas. These spurious or false signals may be isolated or
13 suppressed as indicated herein such that exclusive detection of
14 unshredable debris within the reduction mill is assured.

15 An embodiment of this invention comprises means coupled to
16 the sensor of this invention to obviate or lessen the effect of
17 spurious acoustic signals, which may be induced in or excited
18 by the bar, and which have the same character as the signals of
19 a stone hitting the bar 72, thereby ensuring that only
20 unshredable debris impacts on the sensor bar are recognized.
21 The preferred embodiment of the instant invention includes
22 vibration isolators 96 shown in FIGS. 4 and 5, for example,
23 which are essential in isolating the bar 72 from spurious
24 signals that have the same character as an unshredable debris

1 signal. The vibration isolators 96 are coupled between the
2 acoustic sensor 70 and the reduction mill to suppress or
3 isolate the sensor from the spurious signals generated within
4 the reduction mill which otherwise would be coupled to the
5 transducer 74.

6 Referring to FIGS. 4 and 5, each end of the acoustic
7 sensor 70 and specifically the bar 72 is secured, for example,
8 to a mounting bracket 100, through the vibration isolators 96
9 such as Barry Cup-Mount C-2040-T6 isolators produced by the
10 Barry Controls Corporation. The entire sensing device 70 and
11 more particularly the brackets 100 are secured to the frame or
12 housing of the reduction mill such that the sensing bar 70 is
13 disposed in the plane of the floor of the lower conveyor as
14 shown in FIGS. 4 and 5; with no physical contact between the
15 sensing device and the conveyor. Accordingly, the vibration
16 isolators 96 acoustically isolate the sensing device from the
17 bracket and more specifically from the reduction mill and
18 thereby prevent spurious or false signals from being induced
19 within the bar 74. Although a space or air gap will exist
20 along the transverse extent of the bar in the floor of the
21 conveyor through which some material may be lost, this space or
22 gap may be filled with an acoustically isolating material or
23 spacer to prevent material loss or deterioration of the
24 acoustic isolation or more importantly the deterioration of the

1 signal indicative of the presence of the unshredable debris.

2 Referring to FIGS. 6, 7 and 8, three variations of
3 electronic isolation means coupled to the acoustic sensor 70 to
4 obviate the effect of signals of the same character as the
5 unshredable debris impacting signal to be detected are
6 illustrated for improving the performance of the sensor. The
7 electronic isolation means illustrated allows the signal from
8 the sensor to discriminate between sounds that are truly
9 unshredable debris and those other noises induced or excited in
10 the bar and, thereby, ensure that only the unshredable debris
11 impact on the sensor bar is recognized. In this manner, false
12 alarms are substantially eliminated. Specifically, the
13 electronic differencing technique illustrated in FIGS. 6, 7 and
14 8 provide filtering schemes which sense the presence of
15 unshredable debris and lessen the effects of spurious noise or
16 false signals. In the embodiment of FIG. 6, the apparatus of
17 this invention including the electronic isolation means is
18 illustrated in block diagram format comprising a buffer circuit
19 82 [it being realized that like numbers are utilized to
20 indicate similar or like circuits or elements throughout]
21 coupled to the sensor 70 disposed in the conveyor area. The
22 buffer circuit provides a properly matched interface between
23 the remainder of the processing circuitry and the transducer
24 74. The buffer circuit 82 is coupled to a pair of parallel

1 filter and detector circuits 84a and 84b, respectively. As
2 noted hereinabove and illustrated in FIG. 9, unshredable debris
3 impacts exhibit a different distribution of amplitude with
4 frequency than does the shredable material, which has a
5 spectrum of resonant frequencies, substantially distinctly
6 separated from each other. Thus, the buffer circuit of FIG. 6
7 is coupled to a parallel pair of filter and detector circuits
8 84a and 84b each aligned with a different resonant frequency
9 and each performs a bandpass filter function. The pass band of
10 the filter and detector circuit 84a, for example, is selected
11 to include one frequency band such as that induced by the
12 unshredable debris, for example, 92 of FIG. 9, while the pass
13 band of filter and detector circuit 84b is selected to include
14 a second characteristic frequency such as that induced by the
15 impact of shredable material, 94 of FIG. 9. The selected
16 characteristic frequency includes the maximum amplitude
17 frequency of the respective unshredable debris and shredable
18 material signals. The detector circuit portion of filter and
19 detector circuits 84a and 84b rectifies the input signals
20 thereto providing an envelope of the signals. The output
21 signals from both filter and detector circuits which may
22 comprise the envelope of the input signals thereto, are
23 suitably weighted and coupled to a difference amplifier 102.
24 The balance is such that the signal in the lower frequency pass

1 band of the shredable material noise dominates and holds the
2 setting of the differential amplifier or comparator 102. When
3 unshredable debris strikes the bar, however, the signal in the
4 higher frequency pass band momentarily becomes larger causing
5 the amplifier to switch state. The output is coupled to the
6 threshold circuit 86 which gives the alert or warning
7 indicative of the presence of unshredable debris in the waste
8 material when the amplitude of the output from the difference
9 amplifier exceeds a preselected value. The difference signal
10 developed in the difference amplifier or comparator 102
11 provides a sensitive indication of the presence of unshredable
12 debris in the waste material which eliminates or obviates the
13 effects of the unwanted spurious noise signals, and thereby,
14 reduces false alarms from the noise signals.

15 The embodiments of the electronic differencing techniques
16 of FIGS. 7 and 8 include a plurality of separate sensing
17 systems having separate buffer and filter circuits respectively
18 coupled to a difference amplifier such that the difference
19 signal can be made sensitive to unshredable debris signals in
20 one bar over and above the general sound level, of the other
21 bar, and isolation of the spurious sounds may be readily
22 detected. For example, in FIG. 7, two sensing systems 70c, 70d
23 are disposed in parallel, i.e., in side by side relation,
24 transverse, across the floor of the conveyor area each

1 comprising a bar 72c, 72d and transducer 74c and 74d,
2 respectively. Each sensor monitors a portion of the floor of
3 the conveyor area and the combination thereof spans the entire
4 width of the conveyor such that unshredable debris may contact
5 one bar but not the other. Each sensor, moreover, comprises a
6 buffer and a filter and detector circuit 82c, 82d and 84c and
7 84d, respectively. The output from the filter and detector
8 circuits are each coupled to a difference amplifier 102 as
9 previously indicated with respect to FIG. 6. This electronic
10 circuit isolation means can then be made sensitive to
11 vibrations in the bars which occur in one bar and not the
12 other, but those vibrations which occur in both bars at
13 substantially the same time and reach the differential
14 amplifier with the same characteristic frequencies may then be
15 isolated as being an induced, false, signal producing no output
16 from the difference amplifier. Accordingly, only the strong
17 accentuated impact sound of unshredable debris hitting one of
18 the bars 74c or 72d, respectively, will be passed by the
19 difference amplifier through a threshold circuit 86 as
20 previously indicated to provide the sensitive indication of the
21 presence of unshredable debris in the gathered shredable
22 material.

23 Likewise, in FIG. 8, two sensors 70e and 70f,
24 respectively, each comprise a bar 72e and 72f in series

1 relation, that is, one in front of the other each spanning the
2 floor of the conveyor area and each comprising a
3 transducer 74e and 74f. Each sensor includes a buffer 82e and
4 82f and a filter and detector circuit 84e and 84f. The output
5 of each sensor is coupled from the filter and detector circuit
6 to a difference amplifier 102 and a threshold circuit 86 as
7 explained hereinabove to provide the signal 80 indicative of
8 unshredable debris in the hammer area. It is appreciated that
9 the sensor means of FIGS. 7 and 8 are arranged such that the
10 impacting signal of unshredable debris on one of the associated
11 sensor bars is accentuated whereas extraneous, spurious or
12 false signals are suppressed, as they are induced in both bars
13 in each figure with substantially the same character or
14 characteristic frequency as the signal to be detected and are
15 washed out by the difference amplifier 102.

16 Thus, the sensing bars in both figures are arranged so
17 that the unshredable debris mixed with the shredable material
18 in the conveyor area will impinge or impact on one or the other
19 of the sensor bars, creating the impacting signal to be
20 detected in the respective circuit, whereas in the other
21 circuit no signal is generated. The difference amplifier 102
22 detects this difference and accentuates the detected signal by
23 passing only this signal to the threshold 86. In like manner
24 any spuriously induced vibrations will induce signals in each

1 sensor and associated circuitry at substantially the same
2 instant in time and will be cancelled in the difference
3 amplifier. It should also be noted, that the electronic
4 components depicted within block 85 of FIG. 6 may be
5 substituted for the components designated 84c and 84d in FIG.
6 7 and 84e and 84d in FIG. 8.

7 In the operation of the preferred embodiment of this
8 invention, the waste material including unshedable debris is
9 conveyed by the lower conveyor and is fed into the hammer area
10 20. The flow of material impacts the sensor 70 and more
11 specifically the sensor bar 72 from which the acoustical
12 signals generated therein are detected by the transducer 74
13 which provides electrical impacting signals in response
14 thereto. More particularly, isolation means, for example, the
15 vibration isolators 96 indicated herein isolates the sensor 70
16 and eliminate the effects of noise from within and outside of
17 the hammer mill. The vibration isolators enable the detection
18 of virtually all of the unshredable debris by accentuating the
19 impacting signal over the background. An alternative
20 embodiment of this invention may further includes deflector
21 means to direct the flow of the material within the conveyor
22 area such that impacting contact with the bar is assured. It
23 will be appreciated that, as the present invention is disposed
24 in the conveyor area of the hammer mill, it may also be

1 incorporated into the hammer roll area 20 itself wherein the
2 sensor(s) 70 will detect impacts of unshredable material with
3 the hammers 28 and/or the stationary cutting bars 30.

4 When the transducer 74 exceeds a certain predetermined
5 level, acoustic sensing device 70 will provide an output to
6 the control circuitry which, in turn, will activate the
7 appropriate valves to reverse, preferably, lower conveyor 16.
8 The acoustic sensing device may also provide outputs to the
9 control circuitry to stop the hammer roll 22 and/or initiate
10 audible or visual warnings.

11 All patents and publications mentioned in this
12 specification are indicative of the levels of those skilled in
13 the art to which the invention pertains. All patents and
14 publications are herein incorporated by reference to the same
15 extent as if each individual publication was specifically and
16 individually indicated to be incorporated by reference.

17 It is to be understood that while a certain form of the
18 invention is illustrated, it is not to be limited to the
19 specific form or arrangement herein described and shown. It
20 will be apparent to those skilled in the art that various
21 changes may be made without departing from the scope of the
22 invention and the invention is not to be considered limited to
23 what is shown and described in the specification.

24 One skilled in the art will readily appreciate that the

1 present invention is well adapted to carry out the objectives
2 and obtain the ends and advantages mentioned, as well as those
3 inherent therein. The embodiments, methods, procedures and
4 techniques described herein are presently representative of the
5 preferred embodiments, are intended to be exemplary and are not
6 intended as limitations on the scope. Changes therein and other
7 uses will occur to those skilled in the art which are
8 encompassed within the spirit of the invention and are defined
9 by the scope of the appended claims. Although the invention
10 has been described in connection with specific preferred
11 embodiments, it should be understood that the invention as
12 claimed should not be unduly limited to such specific
13 embodiments. Indeed, various modifications of the described
14 modes for carrying out the invention which are obvious to those
15 skilled in the art are intended to be within the scope of the
16 following claims.

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